Slamming of Catamaran Hulls

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Introduction to Multiscale Engineering

School of Mechanical and Materials Engineering

Introduction

Ships can encounter large structural loads during operation in high seas or at high speeds as a result of slamming. Hull designs must account for these excessive loads in order to ensure safe operation. Slamming of conventional style single-hulls has been studied both a the numerical and experimental levels, but there has been little research into the slamming of multi-hull geometries which arise in catamaran ships, and some air-assisted or air-cavity ships. To further understand the influence of slamming on multi-hulls, a drop testing apparatus has been constructed to study the impact of catamaran style hulls on the water's surface.

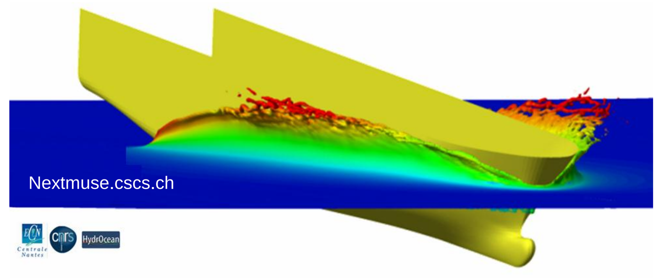

Figure 1: Numerical simulation of slamming on an oil tanker hull

Figure 2: Photo of slamming encountered by a cruise ship

Objective

Design and conduct an experiment to measure peak accelerations of a catamaran hull on entry to the calm water surface

Experimental Apparatus

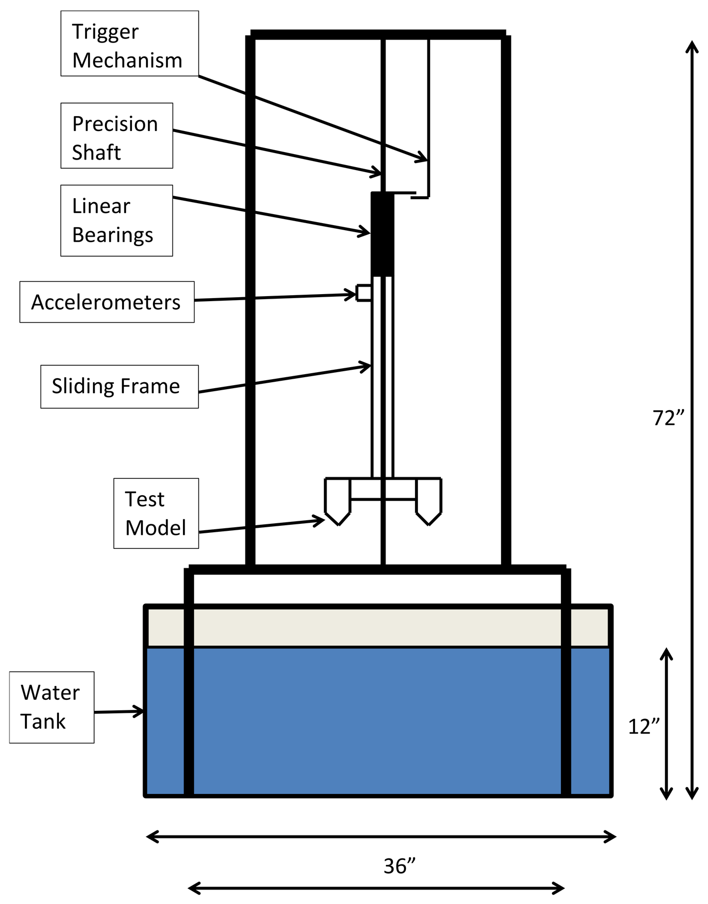

Figure 3: Schematic of drop test rig

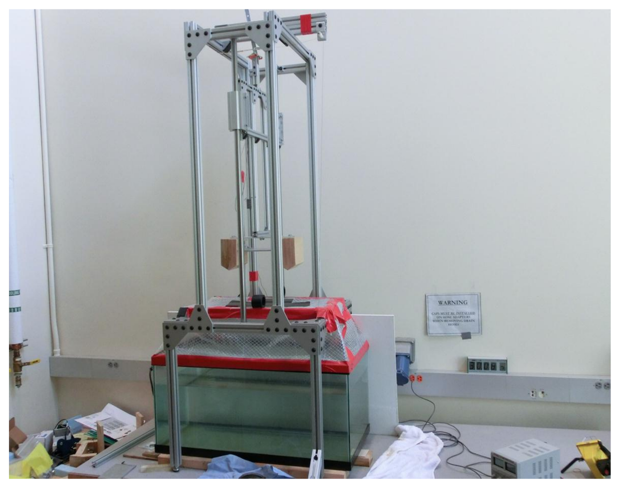

Figure 4: Photograph of drop test experiment

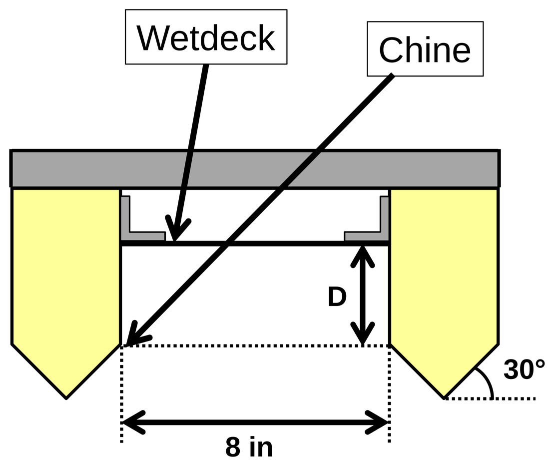

Figure 5: Schematic of the tested catamaran geometry. The chine to wetdeck gap is denoted "D". The deadrise angle is 30 degrees.

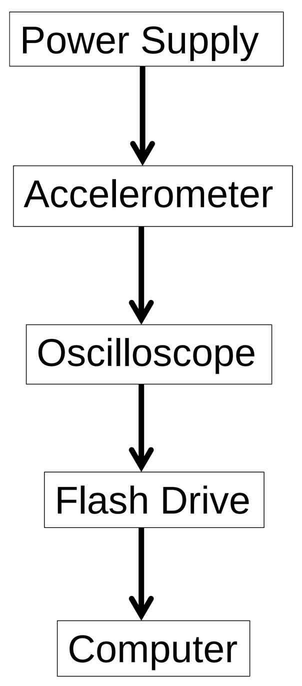

Figure 6: Block diagram of electronic components

Experimental Procedure

First, the power supply was set to deliver the specified excitation voltage to the accelerometers for their proper operation. The oscilloscope was then set to trigger its data acquisition once it detected a spike in voltage from the accelerometer upon impact. The safety on the trigger mechanism was then removed, and the high speed camera was prepared to record. The trigger was pulled thus placing the catamaran into a free fall from the desired drop height. The oscilloscope readout was then checked for error, and the data set for the trial was saved to a flash drive for upload to the computer. The recorded results were time-resolved acceleration, and high speed video of the test.

Experimental Conditions

Test Conditions	D=1.0 in	D=2.5 in
V_{entry}=2.26 m/s	Configuration 1	Configuration 3
V_{entry}=2.73 m/s	Configuration 2	Configuration 4

Four different regimes were chosen in order to broadly study the effects of slamming for various situations. The chine to wetdeck gap, and the velocity of the catamaran entering the water were chosen as variable parameters.

Results

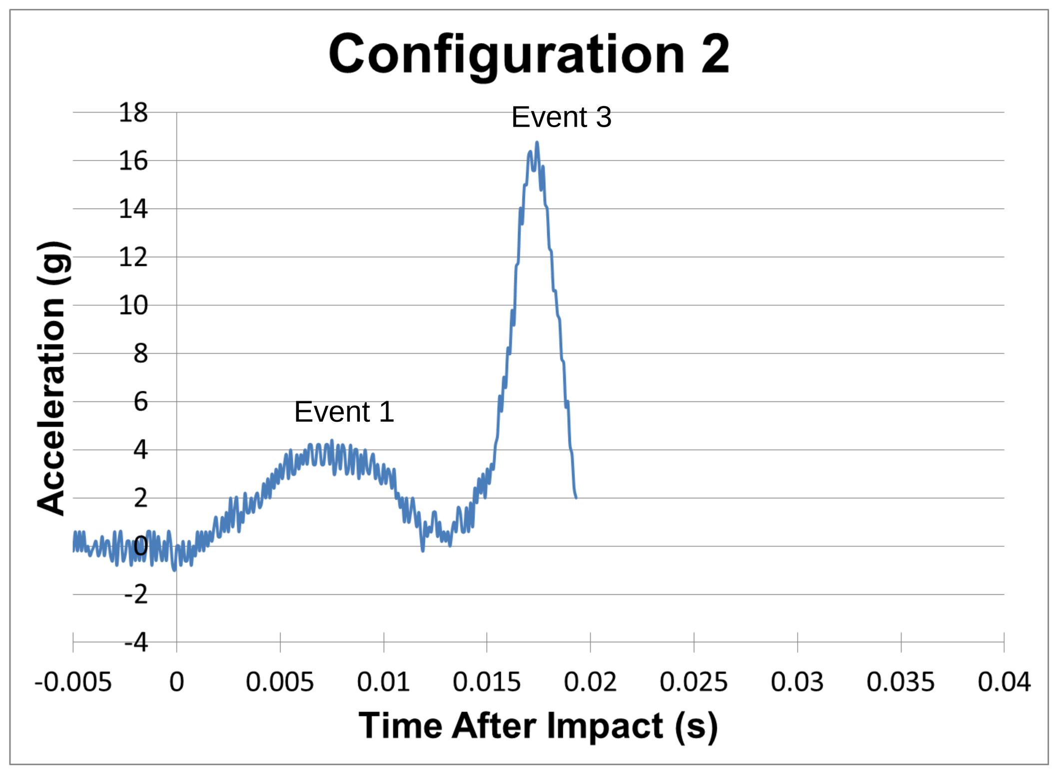

Figure 7: Time dependent acceleration from a drop of Configuration 2. Positive values of acceleration indicate acceleration upward.

Event 1

Figure 8: Chine submergence at t=0.0075 s

Event 3

Figure 9: Wetdeck submergence at t=0.017 s

Key events	Description
Event 1	Chines submerge
Event 2	Spray from chines collides with wetdeck
Event 3	Wetdeck submerges

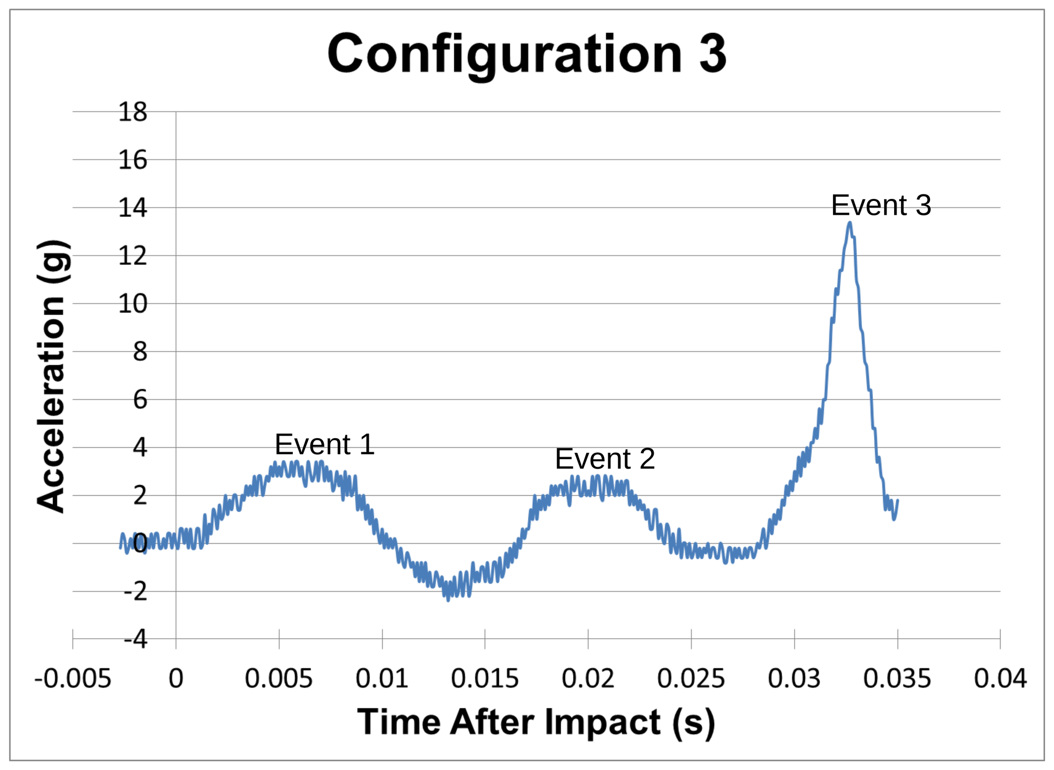

Figure 10: Time dependent acceleration from a drop of Configuration 3. Positive values of acceleration indicate acceleration upward.

Event 1

Figure 11: Chine submergence at t=.006 s

Event 2

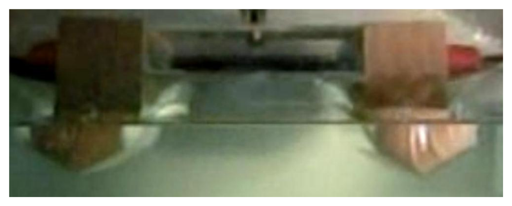

Figure 12: Chine spray hits wetdeck at t=0.02 s

Event 3

Figure 13: Wetdeck submergence at t=0.033 s

Signals were compared with the high speed video footage of the event to help examine the cause of the peaks. The peaks in acceleration were found to correspond with one of three key events in the footage. In tests of Configurations 1 and 2, the spray generated by the chine seemed to collide with the wetdeck as the wetdeck was submerging so there is no presence of Event 2 in these tests.

Analysis

Data obtained from the oscilloscope was in terms of voltage, so in MS Excel, it was converted into acceleration using the sensitivity of the accelerometers. Also using Excel, the values of peak acceleration, and the time at which they occurred after impact were obtained, and summarized in Figure 14.

Velocities were calculated in Excel by using the high speed camera to measure position of the free falling test model as a function of time. This position graph was fitted, and derived twice to obtain the acceleration of the hull under free fall. After two trials, the acceleration of the sliding portion was about 80% of actual gravity due to friction from the bearings, and other sources. Using this actual acceleration due to gravity, $0.8g$, and the drop height, h, the velocity was calculated using a kinetic and potential energy balance as shown.

$$V_{entry} = \sqrt{2 * 0.8g * h}$$

Red denotes high impact velocity, and blue denotes the low velocity in Figure 14. Note the consistently higher accelerations that occur for higher velocities in Events 1 and 2. In general, Events 1 and 2 occur at similar times for all geometries. However, for Event 3, the lower velocity tests have markedly delayed wetdeck submergence.

It is clear that geometries which allow enough space (large D) for the chine spray to contact the wetdeck in a separate event offer lower max slamming loads than those in which Events 2 and 3 are combined. Although there may be equal initial energy, the energy is spread over 3 events instead of 2 resulting in lower max loads on the vessel.

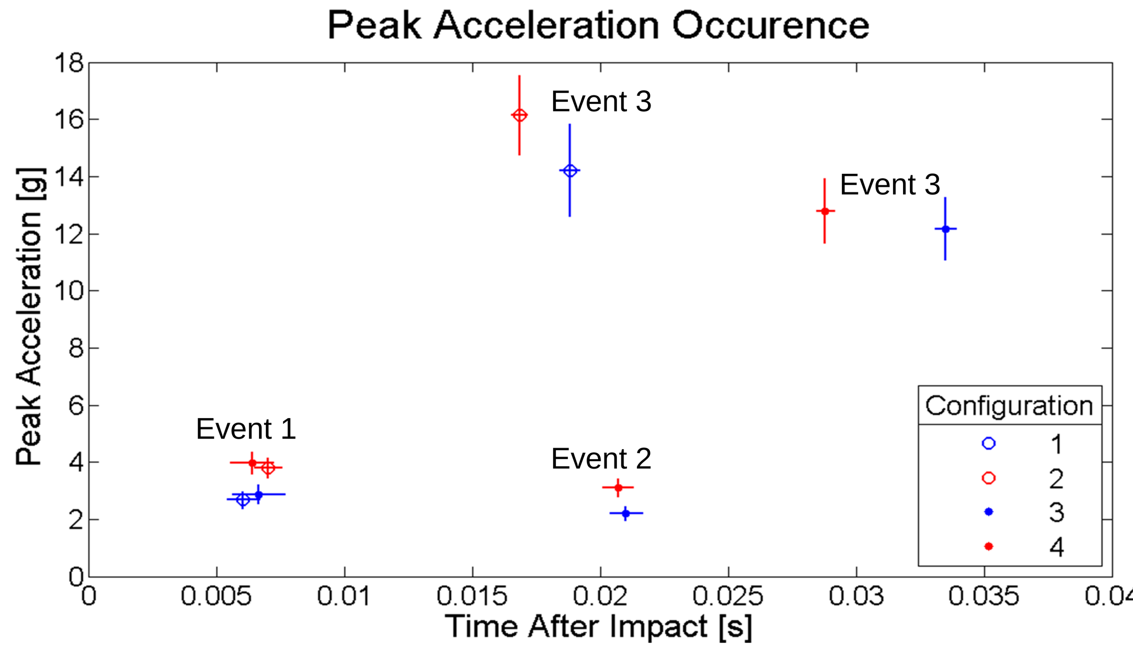

Figure 14: Summary of peak acceleration data. Times of occurrence, and values of acceleration at those peaks were averaged over 5 trials for each geometry.

Laboratory Experiments Under Development

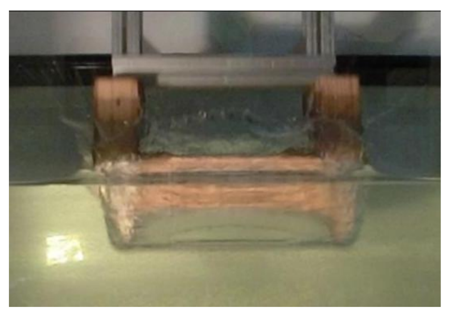

Figure 15: Preliminary drop test of a twin hull model with an air cavity closed from the atmosphere once submerged.

Air assisted marine vehicles such as air-cavity ships typically utilize a hull similar to a catamaran on the underside. Once the cavity is filled with air, water drag converts to air drag, and efficiencies of travel can rise nearly 30%. However, it is unclear how these vessels will perform in slamming conditions, so further studies will examine slamming effects on twin-hull models with air cavities closed from the atmosphere.

Conclusion

There are definitive flow phenomena that occur when a catamaran style multi-hull slams on the waters surface. These events are responsible for the primary slamming loads on catamarans, and multi-hull ships must be designed to account for these effects in order to avoid structural failure.

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